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UTILITY PATENT APPLICATION TRANSMITTAL
(Large Entity)
(Only for new nonprovisional applications under 37 CFR 1.53(b))

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Total Pages in this Submission
32

TO THE ASSISTANT COMMISSIONER FOR PATENTS
Box Patent Application
Washington, D.C. 20231

Transmitted herewith for filing under 35 U.S.C. 111(a) and 37 C.F.R. 1.53(b) is a new utility patent application for an invention entitled:

TRACING TECHNIQUE AND RECORDING MEDIA OF OBJECT MOTION

and invented by:

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Fumiaki Tomita
Yutaka Ishiyama

If a CONTINUATION APPLICATION, *check appropriate box and supply the requisite information:*

☐ **Continuation** ☐ **Divisional** ☐ **Continuation-in-part (CIP)** of prior application No.: _____

Which is a:

☐ **Continuation** ☐ **Divisional** ☐ **Continuation-in-part (CIP)** of prior application No.: _____

Which is a:

☐ **Continuation** ☐ **Divisional** ☐ **Continuation-in-part (CIP)** of prior application No.: _____

Enclosed are:

Application Elements

1. ☒ Filing fee as calculated and transmitted as described below

2. ☒ Specification having _____14_____ pages and including the following:

   a. ☒ Descriptive Title of the Invention

   b. ☐ Cross References to Related Applications *(if applicable)*

   c. ☐ Statement Regarding Federally-sponsored Research/Development *(if applicable)*

   d. ☐ Reference to Microfiche Appendix *(if applicable)*

   e. ☒ Background of the Invention

   f. ☒ Brief Summary of the Invention

   g. ☒ Brief Description of the Drawings *(if drawings filed)*

   h. ☒ Detailed Description

   i. ☒ Claim(s) as Classified Below

   j. ☒ Abstract of the Disclosure

P01ULRG/REV04

Application Elements (Continued)

3. ☒ Drawing(s) *(when necessary as prescribed by 35 USC 113)*

    a. ☒ Formal   Number of Sheets   6

    b. ❑ Informal   Number of Sheets

4. ☒ Oath or Declaration

    a. ☒ Newly executed *(original or copy)*   ❑ Unexecuted

    b. ❑ Copy from a prior application (37 CFR 1.63(d)) *(for continuation/divisional application only)*

    c. ☒ With Power of Attorney   ❑ Without Power of Attorney

    d. ❑ *DELETION OF INVENTOR(S)*
         Signed statement attached deleting inventor(s) named in the prior application,
         see 37 C.F.R. 1.63(d)(2) and 1.33(b).

5. ❑ Incorporation By Reference *(usable if Box 4b is checked)*
     The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.

6. ❑ Computer Program in Microfiche *(Appendix)*

7. ❑ Nucleotide and/or Amino Acid Sequence Submission *(if applicable, all must be included)*

    a. ❑ Paper Copy

    b. ❑ Computer Readable Copy *(identical to computer copy)*

    c. ❑ Statement Verifying Identical Paper and Computer Readable Copy

Accompanying Application Parts

8. ☒ Assignment Papers *(cover sheet & document(s))*

9. ❑ 37 CFR 3.73(B) Statement *(when there is an assignee)*

10. ❑ English Translation Document *(if applicable)*

11. ❑ Information Disclosure Statement/PTO-1449   ❑ Copies of IDS Citations

12. ☒ Preliminary Amendment

13. ☒ Acknowledgment postcard

14. ❑ Certificate of Mailing

     ❑ First Class   ☒ Express Mail *(Specify Label No.):*   EL682144274US

Accompanying Application Parts (Continued)

15. ☒ Certified Copy of Priority Document(s) *(if foreign priority is claimed)*

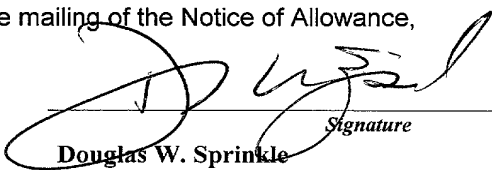16. ☐ Additional Enclosures *(please identify below):*

Fee Calculation and Transmittal

CLAIMS AS FILED

For	#Filed	#Allowed	#Extra		Rate	Fee
Total Claims	8	- 20 =	0	x	$18.00	$0.00
Indep. Claims	2	- 3 =	0	x	$78.00	$0.00
Multiple Dependent Claims (check if applicable) ☐						$0.00
					BASIC FEE	$690.00
OTHER FEE *(specify purpose)*		Assignment Recordal Fee				$40.00
					TOTAL FILING FEE	$730.00

☒ A check in the amount of **$730.00** to cover the filing fee is enclosed.

☒ The Commissioner is hereby authorized to charge and credit Deposit Account No. **07-1180**
as described below. A duplicate copy of this sheet is enclosed.

    ☐ Charge the amount of   as filing fee.

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    ☒ Charge any additional filing fees required under 37 C.F.R. 1.16 and 1.17.

    ☐ Charge the issue fee set in 37 C.F.R. 1.18 at the mailing of the Notice of Allowance,
    pursuant to 37 C.F.R. 1.311(b).

_____
Signature

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Dated: **September 26, 2000**

cc:

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant: Yasushi SUMI et al.

Serial No.:

Filed:

For: TRACING TECHNIQUE AND RECORDING MEDIA OF OBJECT MOTION

PRELIMINARY AMENDMENT

Assistant Commissioner for Patents
Washington, D.C. 20231

Dear Sir:

Prior to the examination of this application, please amend the application as follows:

IN THE CLAIMS:

Claim 3, line 1, after "Claim (1)" delete "or (2)".

Claim 4, line 1, after "Claim (1)" delete "or (2)".

Claim 7, line 1, after "Claim (5)" delete "or (6)".

Claim 8, line 1, after "Claim (5)" delete "or (6)".

If the Examiner has any questions relating to the application, Applicant's attorney may be reached at (248) 647-6000.

Respectfully submitted,

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DWS/llh

TRACING TECHNIQUE AND RECORDING MEDIA
OF OBJECT MOTION

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an object motion tracing technique for tracing the three-dimensional motion of an object obtained in time series on the basis of the stereo image of the object concerned, and also to a recording media wherein an executing program for object motion tracing is recorded.

2. Brief Description of the Prior Art

Generally, for tracing the three-dimensional rigid body movement of a curve-faced object, time-series images consecutively obtained from a visual sensor as an image pick-up means are used. If the form of the traced object is known, the tracing point can be estimated in correspondence search by using a three-dimensional geometric model of the object concerned, thereby realizing highly-accurate tracing of the position and the posture of the curve-faced object, wherein tracing is comparatively unaffected by partial occlusion.

Prior arts known for tracing the three-dimensional rigid body motion of an object using an object model are as follows:

(1) Method of using a monocular CCD camera as a sensor,

(2) Method of applying a stereo camera system consisting of a plural number of CCD cameras as sensors, and

(3) Method of using a range finder as a sensor.

The silhouette of the curve-faced object as mentioned above is an apparent silhouette whose shape consecutively varies according to the position/posture of the object concerned, and it is difficult to estimate and measure its position accurately. Therefore, the objects traced by the above-mentioned prior arts (1) or (2) were limited to those having fixed-edge

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structures that are invariable according to observing directions, such as polyhedrons, cylinders, etc., but arbitrary-curve-faced objects with smooth faces have never been traced by those prior arts. In the prior art (3) above, objects of free forms including arbitrary-curve-faced objects can be traced by utilizing the three-dimensional information on the surface, but a special type of sensor such as a high-speed laser range finder is needed for that purpose.

SUMMARY OF THE INVENTION

The present invention was carried out in consideration of the aforesaid problems, and aims at providing an object motion tracing technique whereby the three-dimensional movement of a curve-faced object is traced accurately at a high speed, utilizing an object model and applying as sensors a stereo camera system consisting of a group of image pick-up cameras.

The object motion tracing technique related to the present invention is a method of tracing the three-dimensional motion of an object, based on the stereo image of the object concerned obtained in time series, composed of a selection step for selecting a tracing point corresponding to the silhouette of the object concerned on the stereo image of aforesaid object, a sampling step for sampling from the stereo image corresponding points on the silhouette of the object corresponding to respective tracing points; a measuring step for measuring the three-dimensional coordinates of the sampled corresponding points, and a detecting step for detecting the position/posture of the object concerned from each of the three-dimensional coordinates of the tracing points and the corresponding points, wherein the three-dimensional motion of the object can be traced by continuously repeating each process on above-mentioned steps from the selecting step through the detecting toward each frame of the stereo image obtained in time series.

A recording media related to the present invention is a media wherein an

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object motion tracing program is recorded for tracing the three-dimensional movement of an object based on the stereo image of the object obtained in time series, composed of a selecting step for selecting tracing points corresponding to the silhouette of the object concerned on the stereo image of the object, a sampling step for sampling from the stereo image the corresponding points on the silhouette of the object corresponding to each tracing point; a measuring step for measuring the three-dimensional coordinates of the sampled corresponding points, and a detecting step for detecting the position/posture of the object from each of the three-dimensional coordinates of the tracing points and the corresponding points, wherein a program is recorded for executing the tracing of the three-dimensional motion of the object by continuously repeating each process on those steps from the selecting step through the detecting one toward each frame of the stereo images obtained in time-series.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG.1 is a block diagram showing a system configuration for embodying the present invention.

FIG.2 is a flow chart showing the flow of basic processing of the present invention.

FIG.3 is an initial picture of time-series stereo image.

FIG.4 is an example of the initial frame of a curve-faced object.

FIG.5 is an example of the net configuration of a curve-faced object model.

FIG.6 is a method of searching for a corresponding edge point.

FIG.7 is a method of searching for a stereo corresponding point.

FIG.8 is a method of three-dimensional estimation of a corresponding point by monocular vision.

FIG.9 is a measurement error of a curve-faced object in stereo vision.

FIG.10 is an example of a tracing result of an arbitrarily-curved object.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Hereinafter the object motion tracing technique of the present invention is described in detail based on the embodiment..

FIG. 1 is a block diagram showing the system configuration for executing the method of generating a three-dimensional object model by the present invention. In this Figure, a numerical sign 1 is a computer to control the entire system, and is connected with each of the under-mentioned parts through data bus 2.

Signs 3a, 3b and 3c stand for television cameras, whose analog output data are transmitted to data bus 2 after being converted to digital signals by A/D Converters 4a, 4b and 4c.

A numerical sign 5 stands for the image memory for storing image data on the object picked up by television cameras 3a, 3b and 3c, while 6 stands for the display unit for displaying the image, numeral 7 shows a printer and 8 a keyboard terminal.

Numeral 9 shows a hard disk unit for storing the system software for the object motion tracing program related to the present invention and storing the three-dimensional geometric model of the object concerned, as well as for consecutively recording the three-dimensional information restored by stereo vision and the information on the object motion parameter obtained by the motion tracing process.

Numeral 10 stands for the CD-ROM Drive for reading CD-ROMs wherein the object motion tracing program is recorded, and the above-mentioned system software is installed onto the Hard Disk 9 from this CD-ROM.

The aforementioned system is connected to an external host computer, etc. via data bus 2.

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FIG. 2 is a flow chart of the basic processing operation in the system of aforesaid configuration, showing the processing flow for tracing the three-dimensional rigid body motion of a curve-faced object on the basis of the stereo image of the object concerned obtained in time-series.

This processing operation is carried out by a program pre-memorized by the Computer 1 in FIG. 1, consisting of:

the input step (S1) where the stereo image of an arbitrary-curve-faced object performing a three-dimensional rigid body motion is inputted as a frame signal from an image pick-up camera applying CCD, etc.;

the selecting step (S2) where the tracing points corresponding to the silhouette of an object on the stereo image of the object concerned is selected;

the sampling (searching) step (S3) where the corresponding point on the silhouette of the object corresponding to each tracing point is sampled from above-mentioned stereo image.;

the measuring step (S4) where the three-dimensional coordinates of the sampled corresponding points are measured (restored);

the detecting step (S5) where the position/posture of the above-mentioned object is detected from each of the three-dimensional coordinates of the tracing points and the corresponding points; and

the discriminating step (S6) where it is discriminated whether the error of measured position/posture of the object concerned is small enough or not, wherein;

the three-dimensional motion of the object is traced by continuously repeating the processing (S2 ~ S5) on each of those steps from the selecting step (S2) through the detecting one (S5) toward each frame of the stereo image obtained in aforementioned time series.

Firstly, a stereo image is inputted (S1), and the tracing points corresponding to the silhouette of a curve-faced object observed on the stereo image are selected based on information on the present position of the object

concerned, using a three-dimensional geometric model (S2). Then, the corresponding points on the silhouette of the object corresponding to respective tracing points are sampled from aforesaid stereo image (S3), so that their three-dimensional coordinates are measured. (S4),

Then, based on the group of the three-dimensional coordinates of respective tracing points and respective measured corresponding points, the position/posture of the object concerned and the error are determined (S5), and it is discriminated whether the error is small enough or not (S6). In case the error is not small enough, then the processes from (S2) above are repeated, regarding the detected position/posture as the renewed present position of the object concerned. If the errors are small enough, the same processes from (S1) above are repeated, regarding the detected position/posture of the object concerned as the renewed present position.

Hereunder the above processes are described in detail, referring to FIG. 3 through FIG.10.

FIG. 3 shows an example of the initial frame (frame 0) of an inputted time-series stereo image. For tracing the motion of an object using a geometric model of the object concerned, it is essential to accurately determine, as the initial tracing position, the three-dimensional position/posture of the object concerned in the initial frame. The description of the method of estimating the initial position of an object is omitted, as it is not necessary here.

FIG. 4 is a drawing showing an example of estimated initial position of an arbitrary-curve-faced object (a toy banana here), together with the three-dimensional silhouette in a scene restored by the segment-based stereo method.

Following is the description of how the tracing points corresponding to the silhouette of a curved object are selected from the object model.

FIG. 5 is an example of net configuration of an object model. Here, an

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arbitrarily-curved object is modeled as a net configuration with nodes of a limited number of representative points (model points) having a spatially neighboring mutual relationship (four couplings).

The silhouette of an arbitrarily-curved object is an apparent silhouette which consecutively transforms according to observing directions. For tracing the motion of an arbitrarily-curved object, the rigid body motion parameters of an object between frames of inputted images in time series and the form of the silhouette varying every moment need to be estimated at the same time.

For that purpose, the form of the hidden silhouette is roughly estimated at a high speed on the basis of the assumed position/posture of an object in a frame, using an object model and the known observing position. It can be discriminated by the following formula whether or not a point on the object surface corresponding to the model point P is observable from the observing the position O at the assumed position of the targeted object.

Formula (1)

$$\text{v i s } (P) = \begin{cases} 1 & \text{i f } (P-O) \cdot N \leq 0 \\ 0 & \text{o t h e r w i z e} \end{cases} \qquad (1)$$

In this formula, N is a normal vector at a point P. Therefore, the hidden silhouette of a curved surface observed on the image can be regarded as the boundary of an area consisting of observable model points, or, it can be regarded to be equal to P in the following formula.

(Formula 2)

$$\begin{cases} \text{v i s } (P) = 1, \\ \displaystyle\sum_{i=1}^{4} \text{v i s } (P_{next(i)}) \neq 4 \end{cases} \qquad (2)$$

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In this formula, $P_{next(i)}$ represents a model point adjacent to P. A group of such model points $\{P_i\}$ can be fetched by the following processes (a) and (b) towards the net configuration of the model.

(a) The nodes satisfying the formula (1) are labeled.

(b) The nodes satisfying the formula (2) are searched out, and starting from the searched node, other nodes satisfying the formula (2) are traced.

These processes can be carried out at a high speed by a simple raster scan. Hidden portions are not checked here, as it is costly to do so.

Motion between frames is estimated by searching for the corresponding points on a following frame image, regarding a number of model points obtained by above-mentioned processing as tracing points. Though three-dimensional movement can be estimated in principle if there are three points that are not on a same straight line, as many tracing points as processing time allows are used here in order to obtain strength against occlusion.

Hereunder the searching procedure for corresponding points is described. Object motion tracing is the repetition of the process for determining the corresponding points in the frame (F r a m e (t + 1)) at a following time $t + 1$ corresponding to the tracing point P at a time t, and can be carried out by processes (c) and (d) below.

(c) Search for a Corresponding Edge Point

From the position P_L where P is projected into the initial image Frame$_L$, pixel is vertically traced to search for the maximal point D_L of the differentiated value of pixel.

(d) Search for a Stereo Corresponding Point

The epipolar line on image Frame$_R$ corresponding to D_L is determined, and as shown in FIG. 7, D_R is searched for in the epipolar line direction as in FIG. 6, from the point P'$_R$ which is the nearest point to the tracing point P_R on the epipolar line.

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These processes are basically differentiation processes for the simple one-dimensional data obtained by tracing, and the calculation cost is small.

Hereunder the restoration of the three-dimensional coordinates of corresponding points by the stereo method is described. The coordinate values of $\{D_L, D_R\}$ searched for by above-mentioned processes are converted to sub pixel based on the inclination of neighboring pixel values, to determine the three-dimensional coordinate D on the basis of the principle of trigonometrical survey.

Generally, when the edge direction of a tracing point is parallel or almost parallel to the epipolar line, binocular stereo measurement causes a bigger error. The easiest way to solve this is to apply a trinocular stereo system with an extra camera Frame $_V$ above or below the baseline of the right and the left stereo cameras. For each of the tracing points, out of the trinocular combinations $\{L, R\}$, $\{L, V\}$ and $\{R, V\}$, a combination with a larger angle formed by the edge direction and the epipolar line is selected to execute the searching process as above-mentioned. Then, for the obtained corresponding point $\{D_i\}$, miscorresponding is eliminated by checking the distance $|P_i - D_i|$ from the model point.

Following is the description of restoration of the three-dimensional coordinates of corresponding point by monocular vision. Search for corresponding points does not always proceed successfully due to occlusion and/or noise. If a corresponding point can be found only monocularly, or only by a binocular combination which is almost parallel to epipolar line, miscorresponding data are eliminated as follows: As shown in FIG. 8, when the end of the vertical line starting from P to the projected line connecting the centers of the camera lenses C and D is regarded as D', miscorresponding data are eliminated for the obtained corresponding point $\{ D_i \}$ by checking the distance $|P_i - D_i|$ from a model point.

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Then, description is made on the method of determining the position/posture and error of the object concerned on the basis of the group of the three-dimensional coordinates of respective measured corresponding points and tracing points. The motion parameter of an object from Frame (t) to Frame (t + 1) can be expressed by 3x3 rotation matrix R and translation vector T, and can be calculated by the least square method in the following formula which minimizes the error in moving $\{P_i\}$ to $\{D_i\}$.

$$\min_{R, T} \sum_{i=1}^{n} | RP_i + T - D_i |^2 \qquad (3)$$

Here, the position/posture of the model is renewed according to calculated R and T. If the error is not small enough, the processes starting from estimation of the hidden silhouette are repeated to make the error convergent by so-called "hill-climbing method". As well known, in measuring the hidden silhouette of a curved surface by stereo vision, the error as shown in FIG. 9 is included. When the baseline length of cameras is l, the distance to the object is d and the curvature of the curving surface concerned is 1 / r, the size of the error e between the hidden silhouette estimated from the model and the value measured by stereo vision may be regarded as $e \doteqdot r \, 1 / 2 \, d$, in case of $1 \ll d$ and $r \ll d$. As e is regarded to be small enough in many cases, it is not taken into account here.

FIG. 10 shows an example of the result of motion tracing experiment using a rotary table for an arbitrarily-curved object model shown in FIG. 3 (Diameter: about 3cm, Space between nodes: about 3mm). The model is moved according to R and T determined in each frame, so that the model nodes are projected onto the inputted image. The experiment proves that tracing is possible under a partial-occlusion environment.

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Thus, this embodiment can realize high-speed and accurate three-dimensional rigid body motion tracing of a curved object utilizing an object model, by applying a stereo camera system consisting of a group of CCD cameras as sensors.

Further, the program for executing the above-mentioned three-dimensional rigid body motion tracing of a curved object can be recorded in an optional recording media, in the form readable by a computer.

As described above, according to the present invention, the three-dimensional motion of a curve-faced object can be traced at a high speed and with accuracy, utilizing an object model, by applying as sensors a stereo camera system consisting of a group of image pick-up cameras.

What is claimed is:

1 Object motion tracing method for tracing the three-dimensional
motion of an object, based on the stereo image of the object concerned
obtained in time series, composed of:

a selecting step for selecting tracing points corresponding to the
silhouette of the object concerned in the stereo image of the object;

a sampling step for sampling from the above-mentioned stereo image
the corresponding points on the silhouette of the object corresponding to
respective tracing points;

a measuring step for measuring the three-dimensional coordinates of
the sampled corresponding points; and

a detecting step for detecting the position/posture of the object from
the three-dimensional coordinates of those respective tracing points and
respective corresponding points,

wherein

the three-dimensional motion of aforesaid object is traced by
continuously repeating each process from the selecting step through the
detecting one toward each frame of the stereo image obtained in time
series.

2. Object motion tracing technique according to Claim (1), wherein
the three-dimensional geometric model of an object is used to select the
tracing points on the selecting step.

3. Object motion tracing technique according to Claim (1) or (2), wherein
the three-dimensional coordinates are measured by stereo vision applying
stereo correspondence on the measuring step.

4. Object motion tracing technique according to Claim (1) or (2), wherein
the three-dimensional coordinates are measured by monocular vision on

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the measuring step.

5.   A recording media wherein an object motion tracing program is recorded for tracing the three-dimensional motion of an object on the basis of the stereo image of the object obtained in time series, composed of:

a selecting step for selecting the tracing point corresponding to the silhouette of the object concerned on the stereo image of the object;

a sampling step for sampling from above-mentioned stereo image the corresponding points on the silhouette of the object corresponding to respective tracing points;

a measuring step for measuring the three-dimensional coordinates for the sampled corresponding points; and

a detecting step for detecting the position/posture of the object from respective three-dimensional coordinates of aforesaid tracing points and corresponding points,

wherein

the program for executing the tracing of the three-dimensional motion of the object by continuously repeating each process from the selecting step through the detecting one as mentioned above toward each frame of the stereo image obtained in time series.

6.   A recording media according to Claim (5) above, wherein the program is recorded for executing the selection of the tracing point using the three-dimensional geometric model of an object on the selecting step.

7.   A recording media according to Claim (5) or (6) above, wherein the program is recorded for executing the measurement of the three-dimensional coordinates by stereo vision applying stereo correspondence on the measuring step.

8.   A recording media according to above Claim (5) or (6), wherein the program is recorded for executing the measurement of the three-dimensional coordinates by monocular vision on the measuring step.

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ABSTRACT OF THE DISCLOSURE

After stereo image is inputted (S1), the tracing point corresponding to the silhouette of a curved object observed by the stereo image is selected on the basis of the information on the present position of the object (S2), using a three-dimensional geometric model. And the corresponding points on the silhouette corresponding to respective tracing points are sampled from the stereo image (S3), and their three-dimensional coordinates are measured (S4). Then, from the group of the three-dimensional coordinates of tracing points and corresponding points, the position/posture of the object concerned and the measurement error are determined (S5), to discriminate the error (S6). In case the error is not small enough, processes starting from (S2) are repeated, regarding the detected position/posture as a renewed present position, while, if the error is small enough, processes are repeated starting from (S1), regarding the detected position/posture as a renewed present position, thereby providing the technique for high-speed tracing of three-dimensional rigid body motion of an arbitrarily-curved and smooth faced object utilizing an object model, applying a stereo camera system as sensors.

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FIG.1

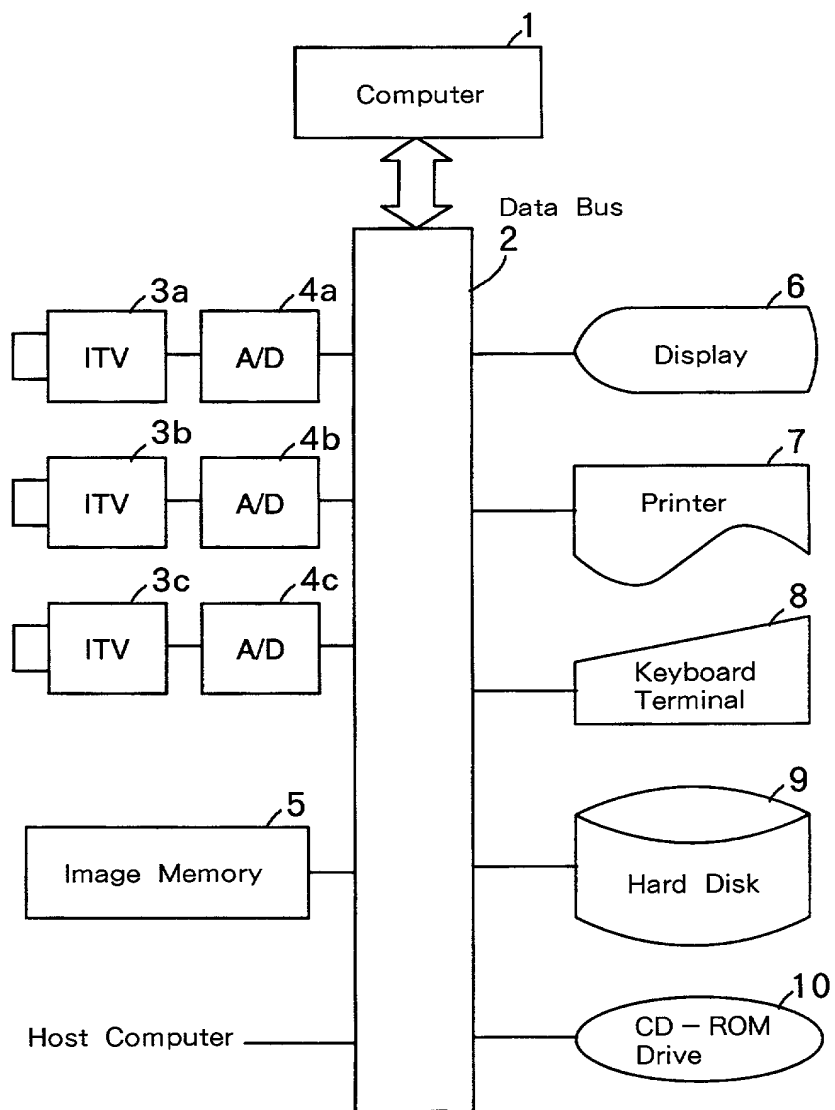System Configuration for Embodying the Present Invention

FIG.2

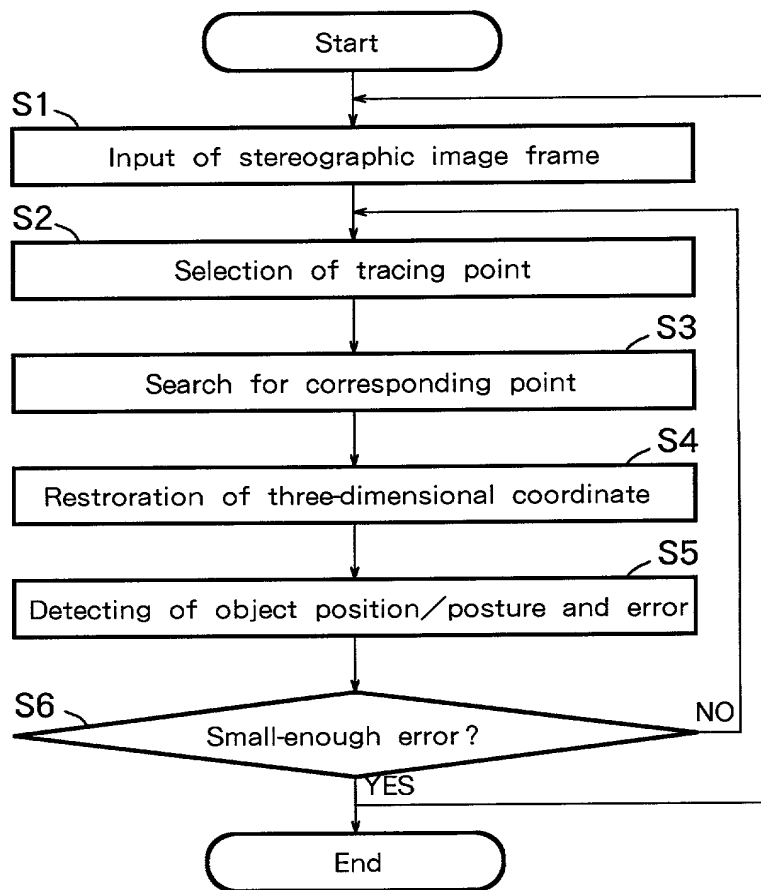Flow of Basic Processing of This Invention

```
                    ┌──────────────────────┐
                    │        Start         │
                    └──────────────────────┘
                               │
   S1                          ▼
  ┌──────────────────────────────────────────────┐
  │      Input of stereographic image frame       │
  └──────────────────────────────────────────────┘
   S2                          │
  ┌──────────────────────────────────────────────┐
  │          Selection of tracing point           │
  └──────────────────────────────────────────────┘
                               │          S3
  ┌──────────────────────────────────────────────┐
  │         Search for corresponding point         │
  └──────────────────────────────────────────────┘
                               │          S4
  ┌──────────────────────────────────────────────┐
  │    Restroration of three-dimensional coordinate │
  └──────────────────────────────────────────────┘
                               │          S5
  ┌──────────────────────────────────────────────┐
  │  Detecting of object position/posture and error │
  └──────────────────────────────────────────────┘
   S6                          │                   NO
        ◇──────────────────────────────────────◇
              Small-enough error ?
                              YES
                               │
                    ┌──────────────────────┐
                    │         End          │
                    └──────────────────────┘
```

FIG.3

An Example of Time-Series Stereo Image
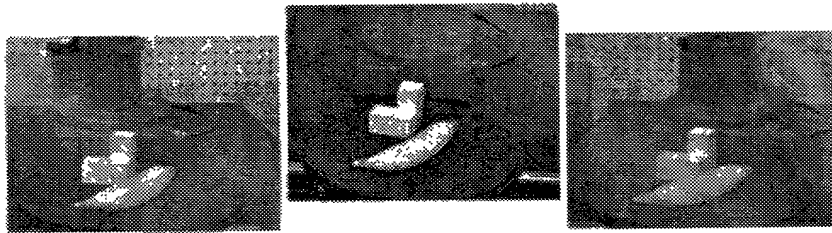
FIG.4

An Example of Estimated Initial Position of a Curve-Faced Object
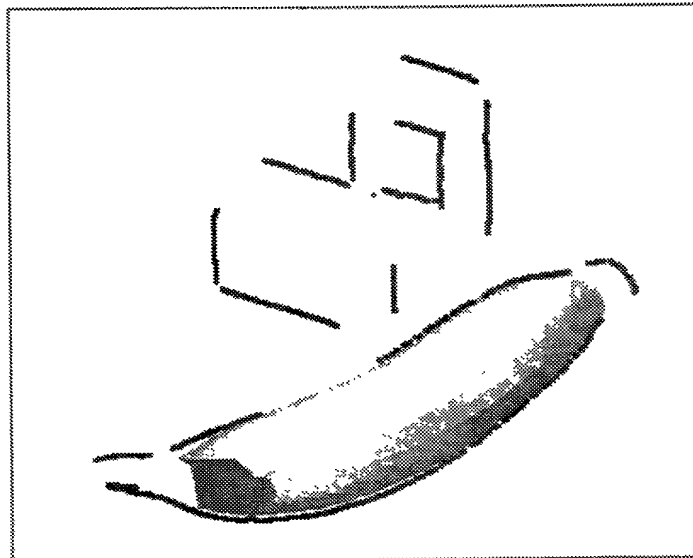
FIG.5

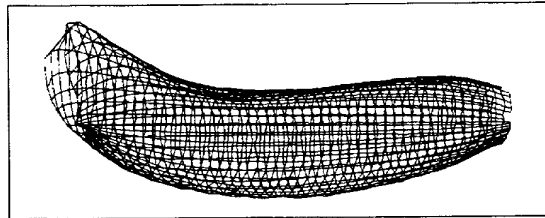An Example of Net Configuration of a Curve-Faced Object Model

FIG.6

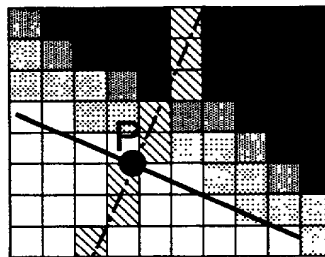Method of Searching for a Corresponding Edge Point

FIG.7

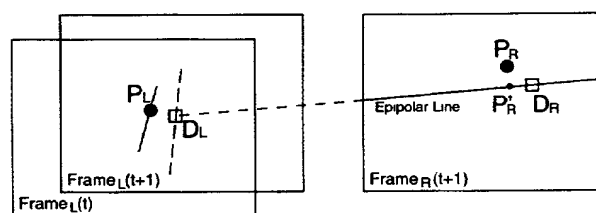Method of Searching for a Stereo Corresponding Point

FIG.8

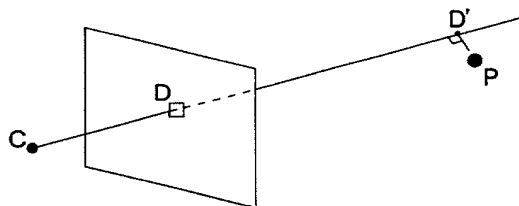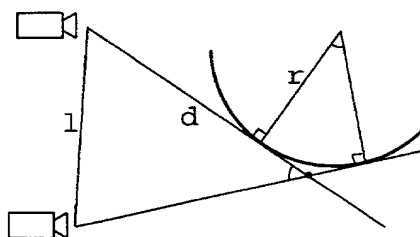Method of Three-Dimensional Estimation of a Corresponding Point by Monocular Vision

FIG.9

Measurement Error of a Curve-Faced Object in Stereo Vision

FIG.10

An Example of a Tracing Result of an Arbitrarily-Curved Object

Frame 20

Frame 70

Frame 120

Frame 170

Docket No.

NWA-15602/04

Declaration and Power of Attorney For Patent Application

English Language Declaration

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

TRACING TECHNIQUE AND RECORDING MEDIA OF OBJECT MOTION

the specification of which

(check one)

☒ is attached hereto.

☐ was filed on _____ as United States Application No. or PCT International

Application Number _____

and was amended on _____

(if applicable)

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119(a)-(d) or Section 365(b) of any foreign application(s) for patent or inventor's certificate, or Section 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate or PCT International application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application(s)			Priority Not Claimed
2000-206818	Japan	7/July/2000	☐
(Number)	(Country)	(Day/Month/Year Filed)	
			☐
(Number)	(Country)	(Day/Month/Year Filed)	
			☐
(Number)	(Country)	(Day/Month/Year Filed)	

I hereby claim the benefit under 35 U.S.C. Section 119(e) of any United States provisional application(s) listed below:

(Application Serial No.)	(Filing Date)
(Application Serial No.)	(Filing Date)
(Application Serial No.)	(Filing Date)

I hereby claim the benefit under 35 U. S. C. Section 120 of any United States application(s), or Section 365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. Section 112, I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, C. F. R., Section 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of this application:

(Application Serial No.)	(Filing Date)	(Status) (patented, pending, abandoned)
(Application Serial No.)	(Filing Date)	(Status) (patented, pending, abandoned)
(Application Serial No.)	(Filing Date)	(Status) (patented, pending, abandoned)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. *(list name and registration number)*

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